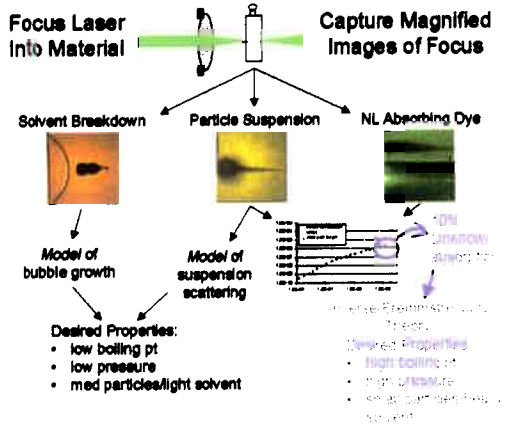
TARDEC ILIR Program

Technical Relevance and Formulation

Problem/Questions: The TARDEC ILIR program addresses fundamental problems related to Army ground vehicle technology.

1) Can nonlinear vehicle dynamic models run in real time?
2) What analysis is required for high resolution terrain characterization?
3) Do tractable models exist of diesel engine combustion physics?
4) What thermal/mechanical affects best attenuate high energy lasers?
5) Can proprioceptive sensors improve UGV mobility?



Significance/Potential Impact:

1) Efficient real-time control of motion base simulators
2) Robust terrain models for real-time mobility analysis
3) High fidelity combustion models for designing diesel engines
4) Sacrificial optical elements for high energy laser protection
5) Improve UGV mobility performance in rough terrain

Dollars **Start Date: Multiple**

($M)	PE	Proj	03	04	05	06	07	08	09
6.1	61101	91A	2.2	2.4	2.4	2.5	2.5	2.6	2.7

Technical Barriers:

1) Optimal mix of linear/nonlinear estimation algorithms
2) Non-stationary/Gaussian statistical models for terrain characterization
3) Spatial/temporal resolution in experimental/analytical studies
4) Laser damage morphology at the liquid/solid interface
5) Integrate proprioceptive sensors into UGV platforms

Future Opportunities/Follow-on Research:

1) Adapt inverse dynamic models for soldier-in-the-loop simulation
2) Incorporate terrain models into real-time dynamic simulations
3) Characterize physics for complex combustion geometries
4) Laser protection for broad band, agile threats
5) Develop mobility behaviors for complex maneuvers/multiple UGVs

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Research Methodology

Methods/Techniques:

- Support vector machine and nonlinear Kalman filters characterize multi-body dynamic vehicles
- 3-D statistical terrain models incorporate Kolmogorov-Smirnov, variogram and universal kriging analysis tools
- Quantify empirical results from an injection calibration test fixture and correlate with peak pressure, duration, flame speed, ignition delay, etc.
- Bubble formation in thick mercury films absorb acoustic shock waves which destroy optical surfaces and their substrates
- Incorporate terrain perception sensor data into a hierarchy of "rule-based" behavior control of UGV mobility functions

Strategy & Rationale:

- These algorithms perform non-linear estimation in large, n-D state spaces
- High resolution spatial/temporal terrain data characterization in parameter spaces with large dynamic ranges.
- Experimental data with limited spatial/temporal resolution is used to validate computational combustion phenomena models
- Empirical testing validates theoretical models of high energy laser disruption by mercury alloy mirrors
- Accurately measure and simulate sensor and vehicle/terrain interactions for the development of complex mobility behaviors

$M (%)	03	04	05	06	07	08	09
Theory	20	20	20	20	20	20	20
Experiment	50	50	50	50	50	50	50
Simulation	30	30	30	30	30	30	30

Can these efforts be accelerated with additional funding? Yes, e.g.

- Exploring flexible injection for increased power density
- Develop atomic behaviors for proprioceptive sensors

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Connection to the Broader Community

Collaboration Activities:

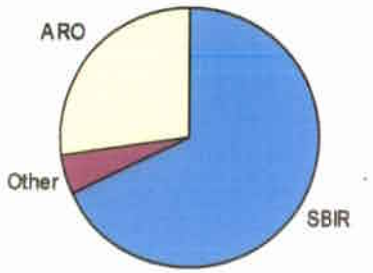
- DARPA Biodynotics, UGCV and Perceptor UGV programs – participation with CMU, U. of Maryland, MIT, Georgia Tech, and SAIC - review boards and collaborative research
- U. of Texas, Center for Electro-mechanics - adaptive suspension and active articulated running gear assemblies for UGV intelligent mobility platforms
- COE ERDC CRREL/WES – vehicle dynamics and terrain characterization
- U. of Michigan, Automotive Research Center (ARC) – participation in research quads with faculty and graduate students
- ARL – robotics and sensor CTAs, ARO - laser material development, joint collaborative efforts and tech transfer.
- Ford Motor Co, SWRI, Wayne State U. and U. of Wisconsin – joint engine/combustion research projects

Others Working This Problem:

- DoE – robotics (Sandia, INEEL), combustion research (Oakridge), innovative mobility mechanisms (Sandia, Oakridge)
- ARL – robotics and sensors (CTA), material development, terrain characterization
- Navy – robotics (SPAWAR), material development (NRL)
- Darpa – robotics, algorithm development, high mobility platforms
- Army – ARL directorates, AMCOM, SOCOM, ARO

Leveraging Other's Efforts:

FY03 ILIR – related funding: $5M



TARDEC ILIR Program

Overall Capabilities and Metrics

Major Accomplishments:

- Bubble model for 25 micron mercury alloy film – good agreement with data
- Fuzzy C-means estimation algorithm used in small robot navigation
- Extension of VV-SVR nonlinear estimation algorithm developed for loss functions in L^p spaces.
- Method for estimating laminar flame speed in diesel fuel
- Mobility behaviors working in ODIS robot – currently in Iraq

Peer Review Results:

Annual ILIR program review:

- Forefront of vector classification algorithms, rule dominance and neural networks
- Qualified and experienced PIs – research production very good
- Excellent vehicle mobility R&D
- Highly relevant to Army needs and requirements

Overall Capability and Metrics:

- 23 peer review articles, 43 conference proceedings articles and 4 patents the last two years
- Currently, ILIR PIs are enrolled in 6 PhD and 2 Masters degree programs
- Last 5 years – ILIR PIs granted 5 PhD and 6 Master degrees
- Several professional awards – i.e. Army Science Conference Best Paper Award
- Three conference and numerous session chairs at technical conferences

TARDEC ILIR Program

Operational Relevance and Technical Transition

Transitions to Date:

- Nonlinear control algorithms in the electro-mechanical active suspension were transitioned to UT-CEM HMMWV, 2.5 ton LMTV and DARPA UGCV prototype
- Laser protection research supports Future Operational Capability (FOC) 09-1 Survivability and Force Protection and will transition directly beginning in FY06 to develop laser protection for FCS spiral integration.
- Control strategies in the ODIS physical security robot, which is currently deployed in Iraq, will result in several hundred manufacturing prototypes in 04.

Opportunities for Transitions:

- Directed energy protection for FCS vehicle
- More reliable failure analysis for wheeled and track vehicles
- Improved UGV mobility via more robust obstacle negotiation
- Nonlinear estimation theory for real-time, man-in-the-loop physical dynamic simulation
- Physics based combustion models for the automotive community (SAE, ASME)

Impacts on the Army and relevance to the Future Force:

- Directed energy protection for multi-threat, high energy lasers
- More fuel efficient, higher power density engines
- Small UGVs with higher levels of autonomy in extreme terrain conditions
- More accurate predictions of Army vehicle life cycle reliability
- More accurate specifications for manned and unmanned vehicle terrain trafficability